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Rahman et al.

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(54) **AERODYNAMICALLY STREAMLINED ACTUATOR ARM FOR DISC DRIVES**

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(22) Filed: **Jun. 9, 2000**

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(60) Provisional application No. 60/138,702, filed on Jun. 11, 1999.

(51) **Int. Cl.**[7] **G11B 5/55**
(52) **U.S. Cl.** **360/266**
(58) **Field of Search** 360/266, 244.2

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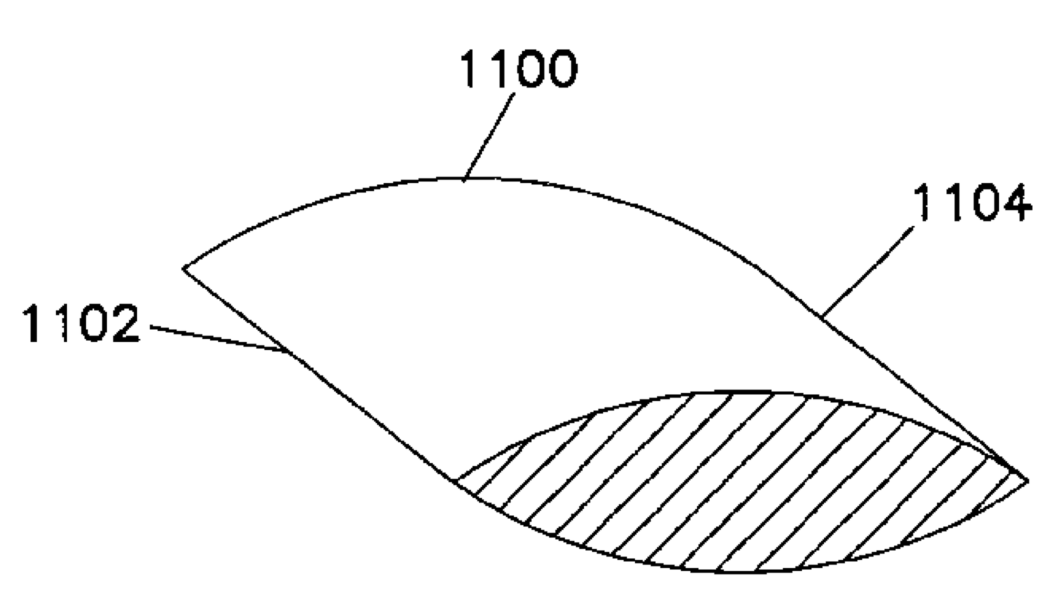
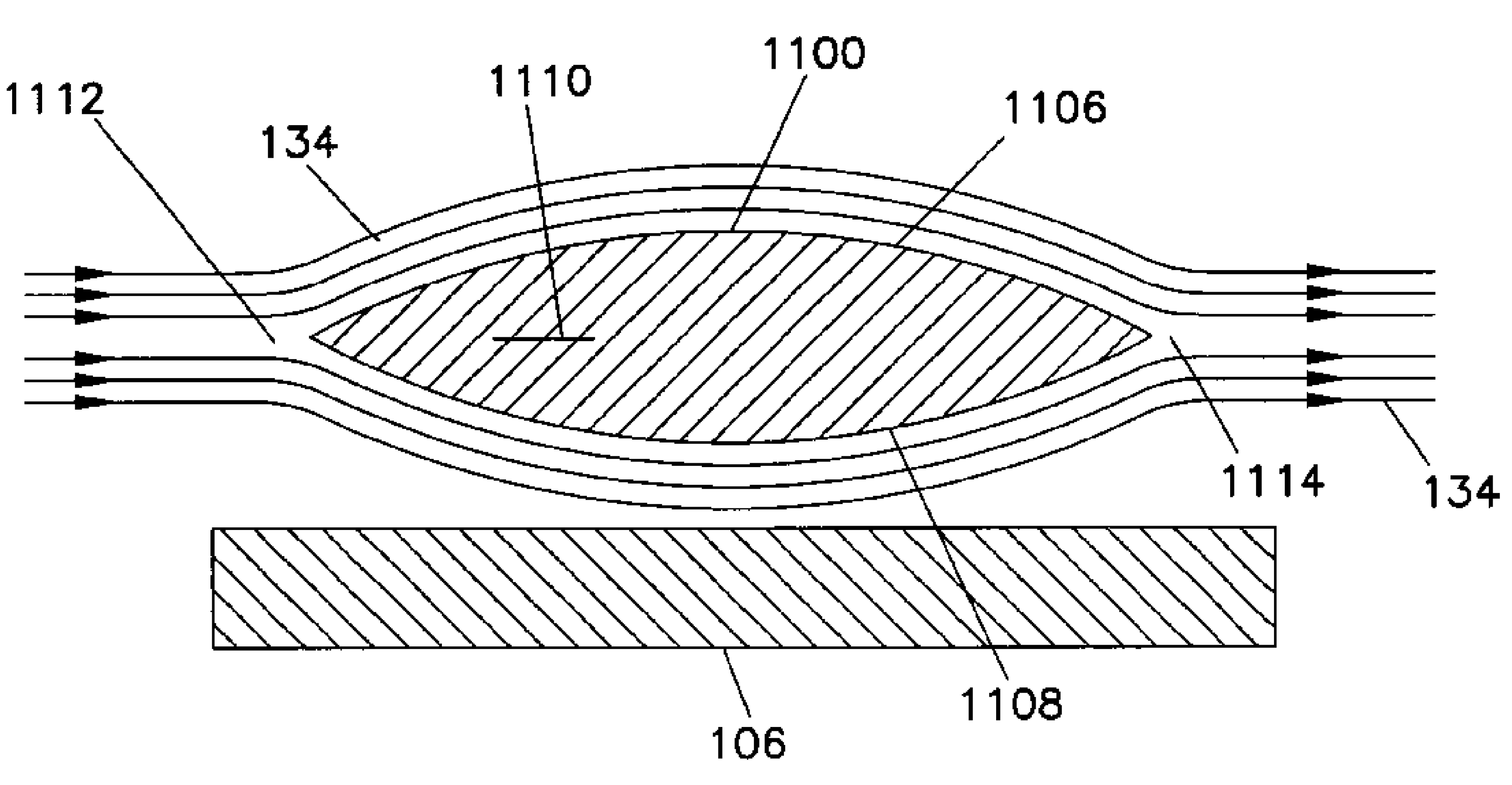
(57) **ABSTRACT**

A disc drive actuator arm is an extended arm having forward edge to engage fluid flow due to rotation of the disc, a rear edge, and a top surface and a bottom surface along which fluid flows. The top and bottom surfaces join the forward and rear edges, and the fluid flow has a boundary layer along the top surface and the bottom surface. The arm has an aerodynamic cross-section so that the fluid flow boundary layer does not separate at the forward and rear edges. The fluid flow past the arm from the forward edge to the rear edge is substantially laminar to prevent vortex shedding.

1 Claim, 5 Drawing Sheets





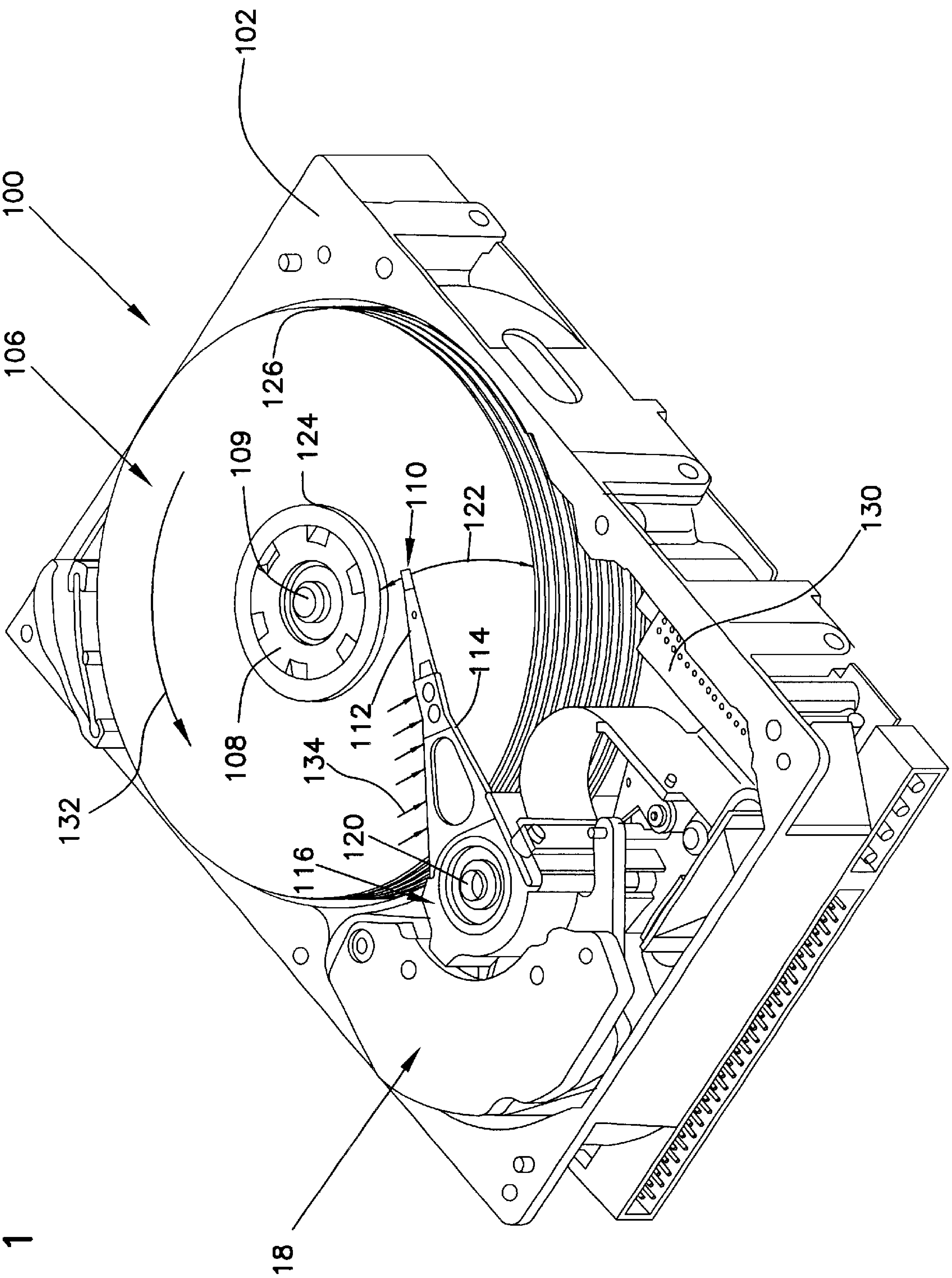

100
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FIG. 1

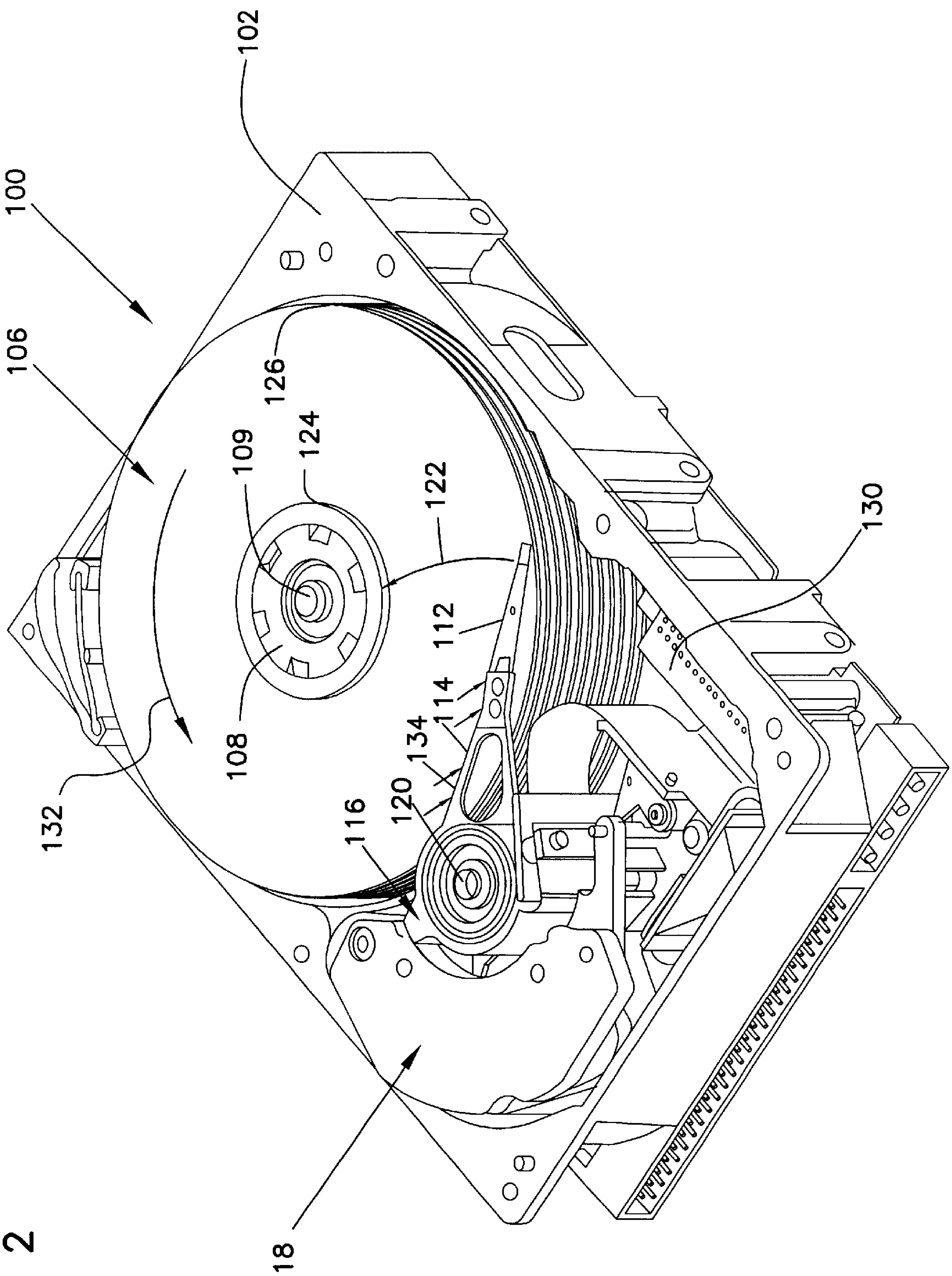


FIG. 2

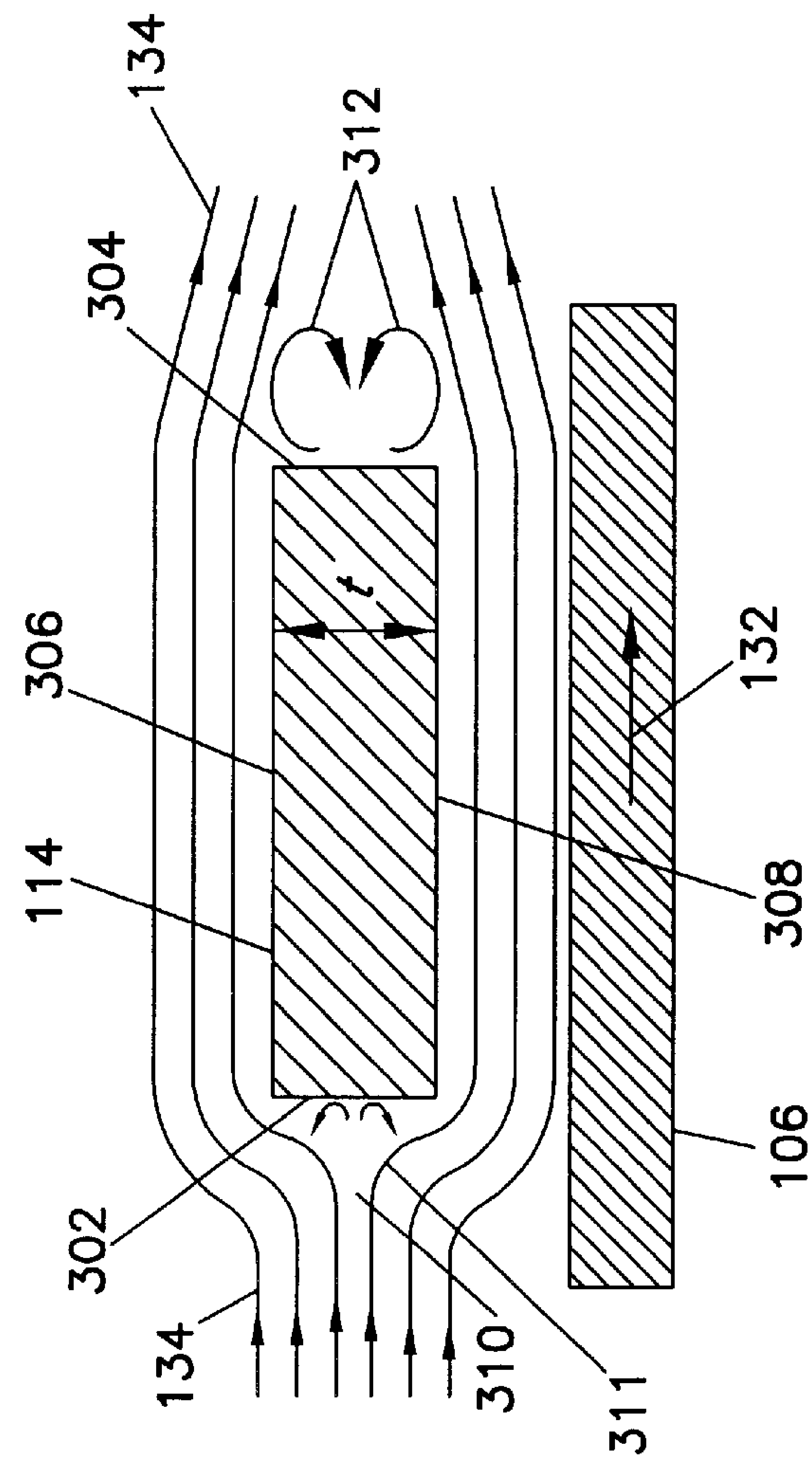


FIG. 4
(PRIOR ART)

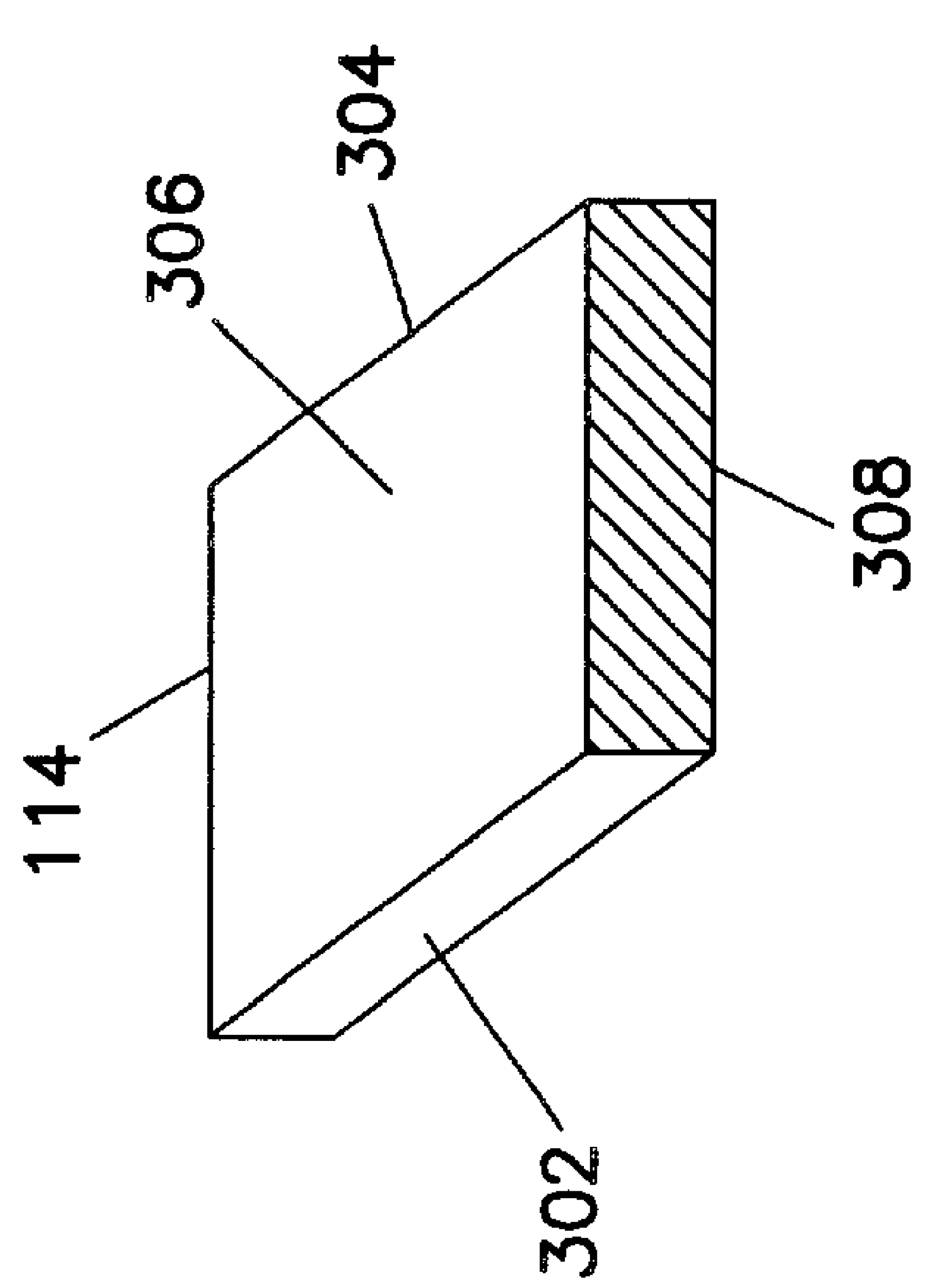


FIG. 3
(PRIOR ART)

FIG. 6

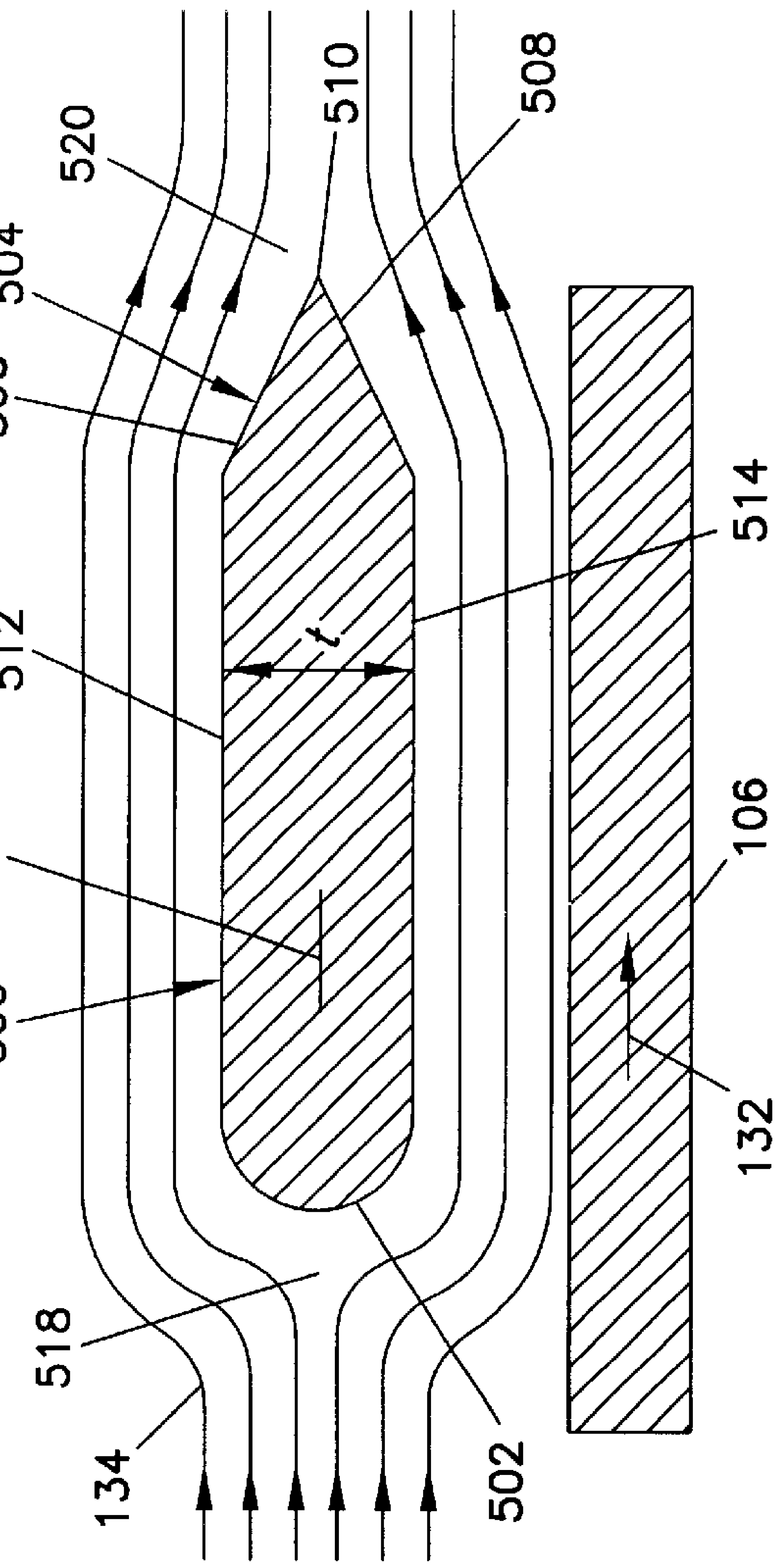


FIG. 8

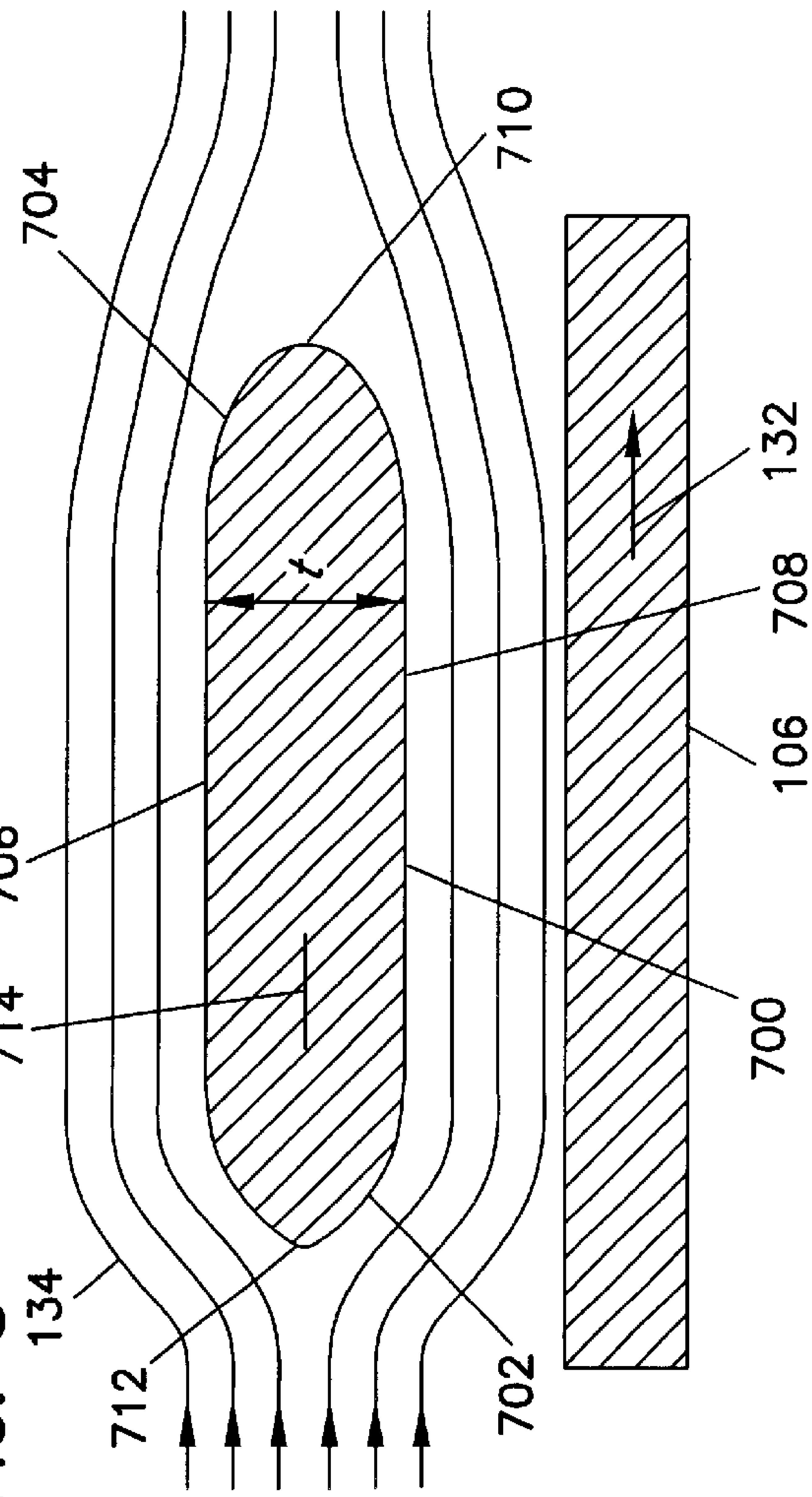


FIG. 5

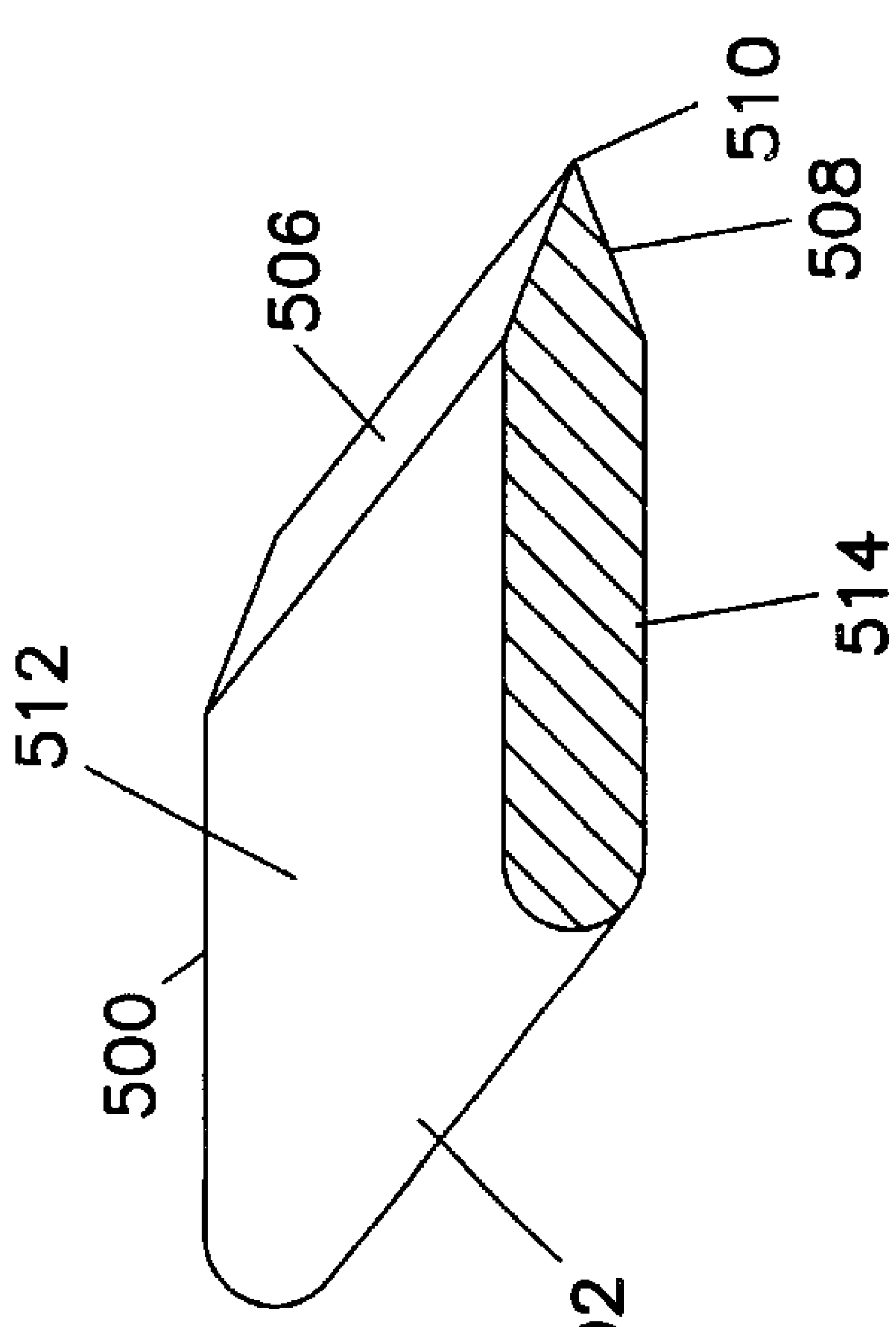
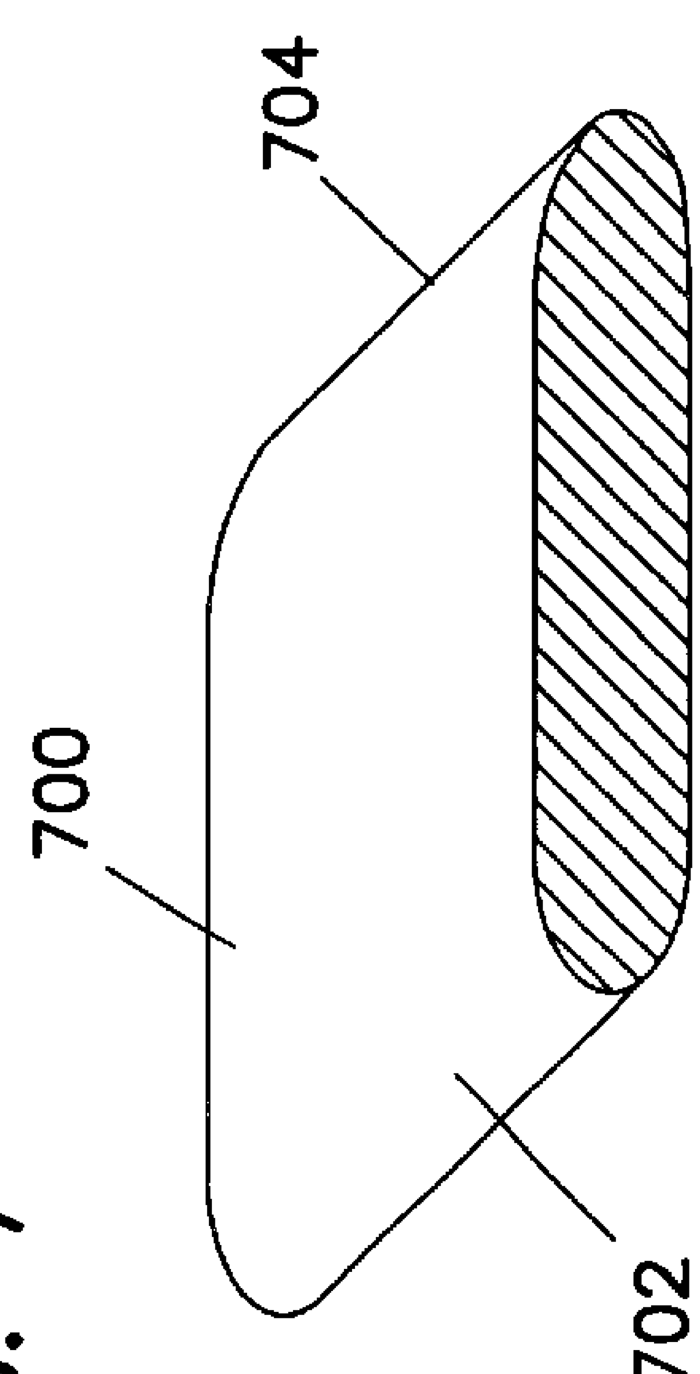


FIG. 7



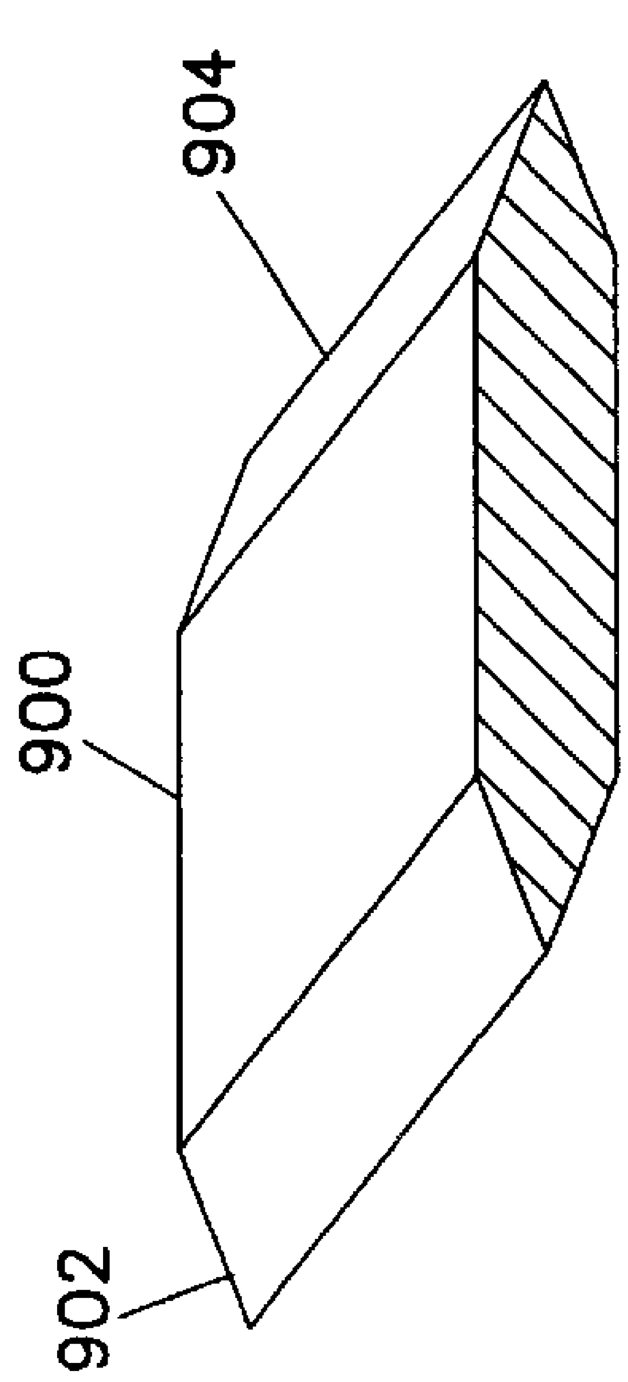


FIG. 9

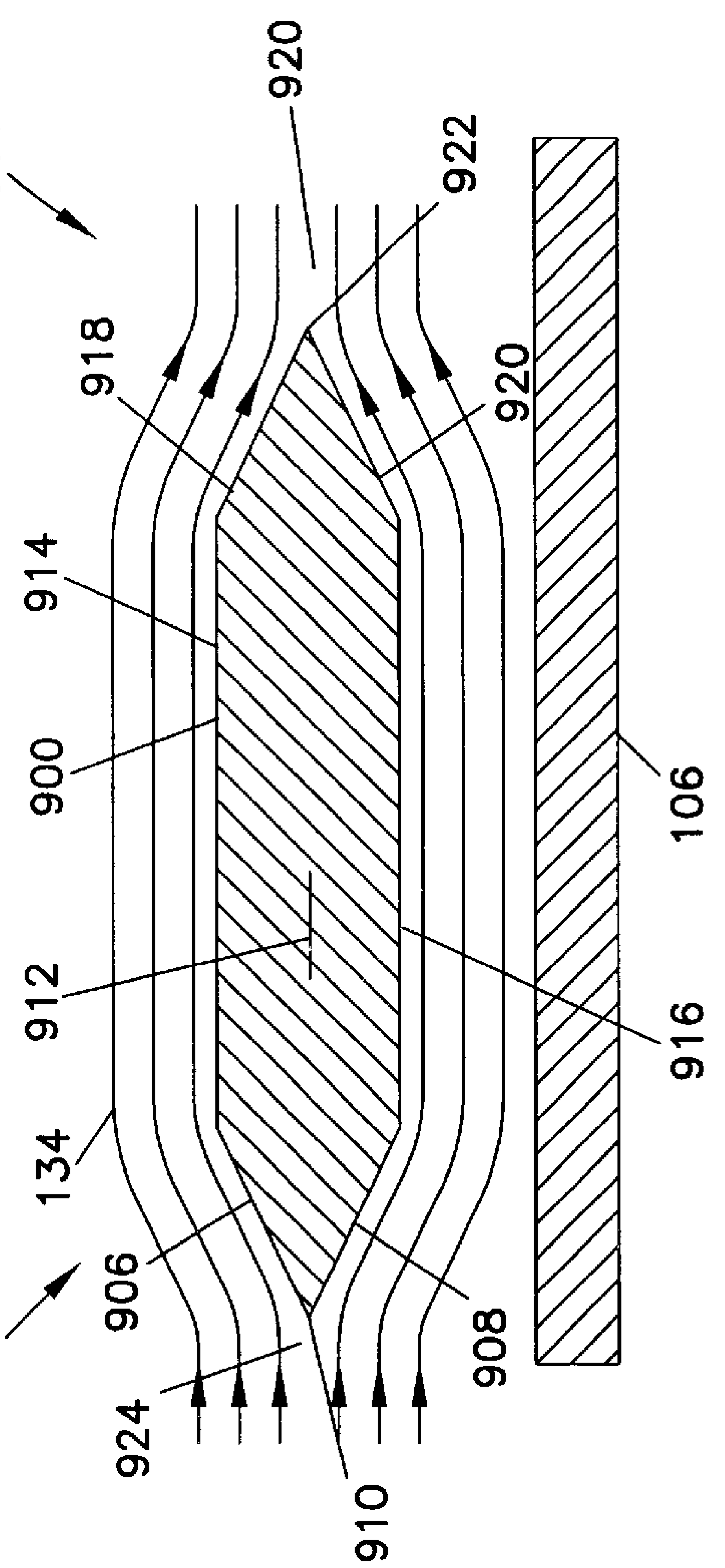


FIG. 10

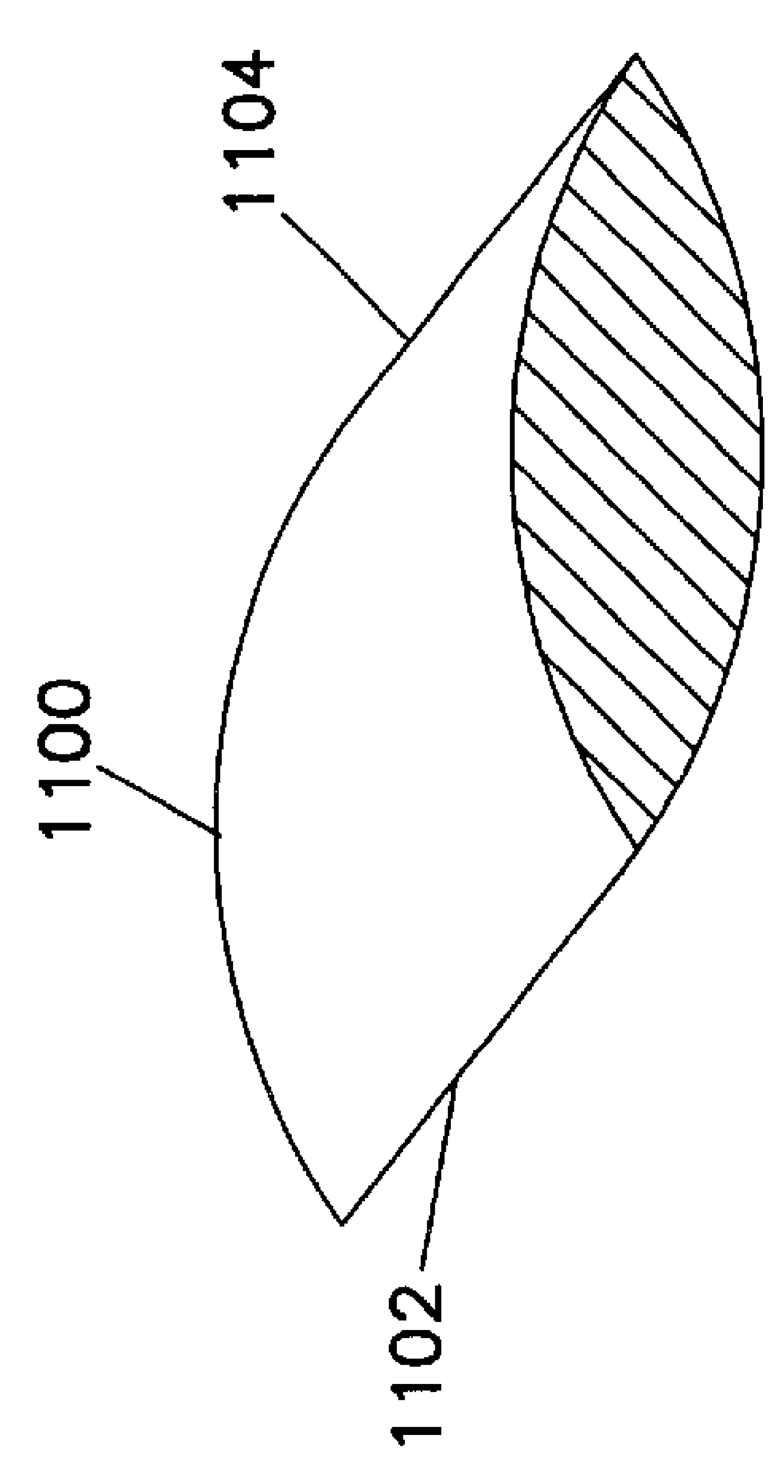


FIG. 11

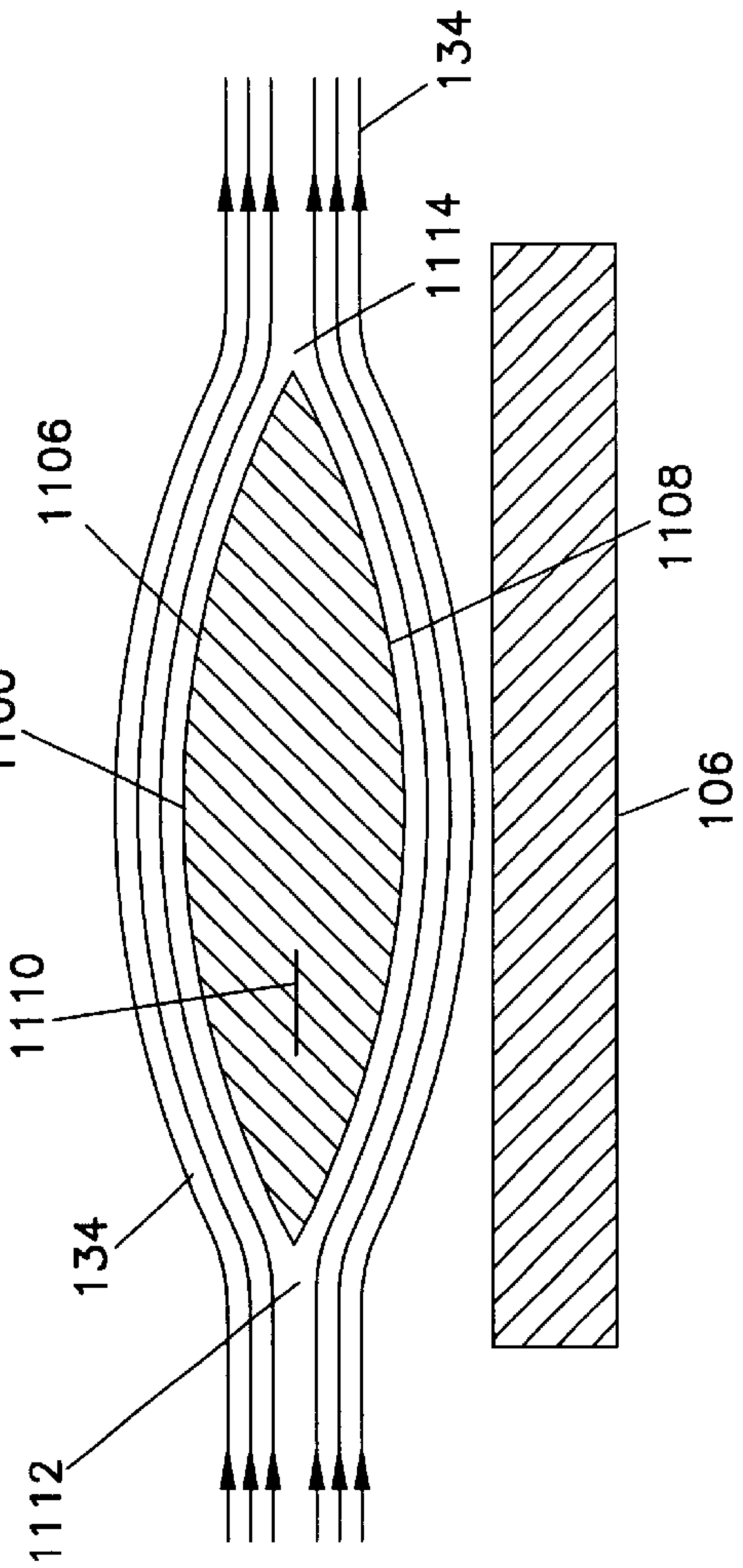


FIG. 12

AERODYNAMICALLY STREAMLINED ACTUATOR ARM FOR DISC DRIVES

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of Provisional Application No. 60/138,702, filed Jun. 11, 1999, for "Streamlined Shape of Actuator Arm" by Mohamed M. Rahman and Hans Leuthold.

FIELD OF THE INVENTION

This invention relates to actuator arms for disc drives, and particularly to actuator arms that are aerodynamic to reduce pressure perturbations within the disc drive.

BACKGROUND OF THE INVENTION

Conventional actuator arms used in disc drives have rectangular cross-sections. The rectangular shape of conventional actuator arms offers substantial resistance to the laminar flow of air associated with a revolving disc. This resistance sheds vortices downstream from the actuator arm, creating a turbulent air flow and vortices in the form of pressure perturbations. These pressure perturbations act as a force against the disc, causing the disc to vibrate in its resonance modes, increasing non-repeatable run-out. Also, the rectangular shape of the actuator arm causes the boundary layer of the flow to separate from the arm just before and just after the actuator arm. A separated flow is inherently unstable and causes pressure perturbations around the actuator arm. These pressure perturbations cause the actuator arm to resonate at its natural frequency, which severely restricts the ability of the servo control system to position the arm accurately relative to the disc surface. This limits the maximum track density in the media.

In addition, the velocity of the air flow is related to the linear velocity of the disc. The linear velocity of the disc is greater at outer tracks than at inner tracks, so the flow velocity of the air varies radially across the disc. Consequently, the pressure perturbations created by actuator arms are different across the disc radius.

The present invention provides a solution to this and other problems, and offers other advantages over the prior art.

SUMMARY OF THE INVENTION

According to one embodiment of the present invention, a disc drive actuator arm is provided to position a head relative to a track on a rotating disc. The actuator arm is an extended arm having a forward edge to engage fluid flow due to rotation of the disc, a rear edge, and a top surface and a bottom surface along which fluid flows. The top and bottom surfaces join the forward and rear edges, and the fluid flow has a boundary layer along the top surface and the bottom surface. The arm has an aerodynamic cross-section so that the boundary layer does not separate at the forward and rear edges.

In preferred embodiments, the forward edge is aerodynamically shaped to minimize pressure increases in front of the arm. In other preferred embodiments, the fluid flow is laminar to prevent shedding vortices.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a disc drive in which aspects of the present invention may be practiced; FIG. 1 showing the actuator arm positioning the head near an inner track radius of the disc.

FIG. 2 is a perspective view of the disc drive shown in FIG. 1 showing the actuator arm positioning the head near an outer track radius of the disc.

FIG. 3 is a perspective view of a prior art actuator arm.

FIG. 4 is a section view of the prior art actuator arm illustrating the effect of air flow on the actuator arm and the adjacent disc.

FIG. 5 is a perspective view of an aerodynamic actuator arm according to a first embodiment of the present invention.

FIG. 6 is a section view of the actuator arm shown in FIG. 5 illustrating the effect of air flow on the actuator arm and the adjacent disc.

FIGS. 7 and 8 are perspective and section views, respectively of an aerodynamic actuator arm according to a second embodiment of the present invention.

FIGS. 9 and 10 are perspective and section views, respectively of an aerodynamic actuator arm according to a third embodiment of the present invention.

FIGS. 11 and 12 are perspective and section views, respectively of an aerodynamic actuator arm according to a fourth embodiment of the present invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

FIG. 1 is a perspective view of a disc drive **100** in which the present invention is useful. Disc drive **100** includes a housing with a base **102** and a top cover (not shown). Disc drive **100** further includes a disc pack **106**, which is mounted on a spindle motor (not shown), by a disc clamp **108**. Disc pack **106** includes a plurality of individual discs, which are mounted for co-rotation about central axis **109**. Each disc surface has an associated disc head-slider **110** that is mounted to disc drive **100** for communication with the confronting disc surface. Head-slider **110** includes a slider structure arranged to fly above the associated disc surface of an individual disc of disc pack **106**, and a transducing head arranged to write data to, and read data from, concentric tracks on the confronting disc surface. In the example shown in FIG. **1**, head-sliders **110** are supported by flexible suspensions **112** which are in turn attached to track accessing, or actuator, arms **114** of an E-block **116**. E-block **116** is driven by a voice coil motor (VCM) **118** to rotate E-block **116** and actuator arms **114**, and their attached heads **110**, about a pivot shaft **120**. Rotation of actuator arms **114** moves the heads along an arcuate path **122** to position the heads over a desired data track between a disc inner diameter **124** and a disc outer diameter **126**. Voice coil motor **118** is driven by servo electronics included on circuit board **130** based on signals generated by the heads of head-sliders **110** and a host computer (not shown). Read and write electronics are also included on circuit board **130** to supply signals to the host computer based on data read from disc pack **106** by the read heads of head-sliders **110**, and to supply write signals to the write head of head-sliders **110** to write data to the discs.

As disc **106** rotates in the direction of arrow **132**, air is carried by the disc to cause an air flow in the same direction. The air flow is generally circular about axis **109**, so the linear flow velocity is greater at the outer track **126** than at the inner track **124**. The rectangular cross-section of actuator arm **114** engages the flowing air, creating vortices and pressure perturbations. Moreover, when the actuator positions heads **110** to access an inner track **124**, as illustrated in FIG. 1, the actuator arm engages the air flow **134** across a substantial portion of the disc radius. As shown in FIG. **2**, when the actuator positions heads **110** to access an outer track **126**, the actuator arm engages the air flow **134** across a smaller portion of the disc radius. Therefore, the problem of vortices and pressure perturbations is more exasperated when the actuator positions heads **110** adjacent inner tracks.

FIGS. **3** and **4** illustrate the perspective view and flying characteristics of prior art actuator arm **114**. Actuator arm **114** has a substantially rectangular cross-section, illustrated in FIGS. **3** and **4**, with a forward surface **302** confronting the air flow **134** and a rear surface **304** parallel to forward surface **302** on the opposite side of the arm. Top surface **306** and bottom surface **308** are parallel to each other and normal to forward and rear surfaces **302** and **304**. The actuator arm is part of an E-block having one end arranged to rotate about axis **120**, and the opposite end arranged to receive suspension **112** and head **110**, as shown in FIG. **1**.

As illustrated particularly in FIG. **4**, the air flow **134** directly meets the forward edge **302** of actuator arm **114**. Since surface **302** is substantially normal to the flow, the air flow in region **310** is substantially stagnant. With a stagnant flow, air pressure in region **310** immediately in front of surface **302** is high and equal to a stagnation pressure, forming vortices **311**. The forward surface, being normal to the direction of air flow, forces air to flow nearly parallel to surface **302**, with one branch of the flow being toward disc **106**. Disc **106** is also moving in the direction of arrow **132**, parallel to the primary path for air flow **134**. Consequently, the disc and air are moving at nearly the same velocity and in the same direction. Consequently, insofar as the disc is concerned, the motion of air at the forward surface **302** is primarily downward, against the disc. At the same time, the substantially normal rear surface **304** strips off vortices **312** adjacent the rear surface **304**. Again, because the primary flow path **134** of air is at nearly the same speed and direction as disc **106**, the vortices are not centered at a midpoint on the thickness τ on arm **114**, but instead are displaced closer to disc **106**. The consequence of vortices **311** and **312** adjacent the spinning disc **106** is that vibration of disc **106** is generated, leading to non-repeatable run-out.

Also, the rectangular shape of actuator arm **114** causes the boundary layer of the flow **134** to separate from the arm at or just before forward surface **302** and at or just after rearward surface **304**. A separated flow is inherently unstable and causes pressure perturbations around actuator arm **114**. These pressure perturbations cause actuator arm **114** to resonate at its natural frequency, which severely restricts the ability of the servo control system to position the arm accurately relative to the disc surface. This limits the maximum track density in the media. The present invention, illustrated in FIGS. **5–12**, overcomes the problems of the actuator arm illustrated in FIGS. **3** and **4**.

FIGS. **5** and **6** illustrate an actuator arm **500** having a forward surface **502** and a rear edge **504**. Forward surface **502** is substantially circular, or elliptical, projected about a mid-plane **516** between the top surface **512** and bottom surface **514**. Surfaces **506** and **508** form the rear edge **504** of actuator arm **500**, and converge at a point **510** on mid-plane **516**, midway between surfaces **512** and **514**. Thus, actuator arm **500** is symmetrical about plane **516**.

Forward surface **502**, being the most forward point of arm **500** at the center plane **516**, serves to divert the air flow **134** to a laminar flow from the forward edge of actuator arm **500** and along the top surface **512** and bottom surface **514**. Consequently, the flow glides smoothly over the top surface **512** and the bottom surface **514** and build-up of pressure in region **518** is minimized. Point **510** at the rear surface **504** of the arm, also centered on center plane **516**, serves to draw the air flow back to the center plane smoothly, thereby maintaining a substantially laminar flow and minimizing vortices and pressure perturbation at region **520**. The boundary layer of fluid flow **134** does not separate at the forward edge **502**, nor at rear surfaces **504** and **506**. The laminar flow adjacent the top and bottom surfaces prevents the shedding of vortices. The aerodynamic cross section of arm **500** helps fluid flow **134** stay laminar as it flows from forward surface **502** to rear surface **504** and thereafter. Consequently, vibration of disc **106** and actuator arm **500** is minimized.

FIGS. **7** and **8** illustrate an actuator arm **700** having a forward surface **702** and a rear surface **704**. Forward surface **702** and rear surface **704** are each substantially elliptical, projected about a mid-plane **714** between the top surface **706** and bottom surface **708**. Thus, actuator arm **700** is symmetrical about plane **714**.

As in the case of the embodiment of FIGS. **5** and **6**, forward surface **702**, being the most forward point of arm **700** at the center plane **714**, serves to divert the air flow **134** to a laminar flow from the forward edge of actuator arm **700** and along the sides top surface **706** and bottom surface **708**. Consequently, build up of pressure in region **712** is minimized and the fluid boundary layer does not separate. Rear surface **704**, also centered on center plane **516**, serves to draw the air flow back to the center plane, thereby keeping the boundary layer from separating and maintaining a substantially laminar flow and minimizing vortices and pressure perturbation at region **710**. Consequently, vibration of disc **106** and actuator arm **700** is minimized.

FIGS. **9** and **10** illustrate an actuator arm **900** having a forward edge **902** and a rear edge **904**. Forward edge **902** is formed by surfaces **906** and **908** that converge at point **910** on mid-plane **912**. Mid-plane **912** is half way between top surface **914** and bottom surface **916**. Surfaces **918** and **920** form the rear edge **904** of actuator arm **900**, and converge at a point **922** on mid-plane **912**, midway between surfaces **914** and **916**. Thus, actuator arm **900** is symmetrical about plane **912**.

Point **910**, being the most forward point of arm **900** at the center plane **912**, serves to divert the air flow **134** to a laminar flow from the forward edge of actuator arm **900** and along the top surface **914** and bottom surface **916**. Consequently, build up of air pressure in region **924** front of point **910** is minimized and the fluid boundary layer does not separate. Point **922** at the rear edge **904** of the arm, also centered on center plane **912**, serves to draw the air flow back to the center plane, thereby keeping the boundary layer from separating and maintaining a substantially laminar flow and minimizing vortices and pressure perturbation at region **926**. Consequently, vibration of disc **106** and actuator arm **900** is minimized.

FIGS. **11** and **12** illustrate an actuator arm **1100** having a forward edge **1102** and a rear edge **1104**. The top surface **1106** and bottom surface **1108** are substantially elliptical or circular about respective projection lines equidistant from mid-plane **1110** as to form forward edge **1102** and read edge **1104** at mid-plane **1110** between the top surface **1106** and bottom surface **1108**. Thus, actuator arm **1100** is symmetrical about plane **1110**.

Forward edge **1102**, being the most forward point of arm **1100** at the center plane **1110**, serves to divert the air flow **134** to a laminar flow from the forward edge of actuator arm **1100** and along the top surface **1106** and bottom surface **1108**. Consequently, build up of air pressure in region **1112** in front of edge **1102** is minimized and the fluid boundary layer does not separate. Rear edge **1104**, also centered on center plane **1110**, serves to draw the air flow back to the center plane, thereby keeping the boundary layer from separating and maintaining a substantially laminar flow and minimizing vortices and pressure perturbation at region **1114**. Consequently, vibration of disc **106** and actuator arm **1100** is minimized.

The present invention thus provides a disc drive actuator arm **500, 700, 900, 1100** for positioning a head **110** relative to a track on a rotating disc **106**. The actuator arm is an extended arm having forward edge **502, 702, 902, 1102** to engage fluid flow **134** due to rotation of the disc. The arm has a rear edge **504, 704, 904, 1104**. Fluid flows along a top surface **512, 706, 914, 1106** and a bottom surface **514, 708, 916, 1108** that join the forward and rear edges. The arm has an aerodynamic cross-section so that the boundary layer of fluid flow does not separate at the forward and rear edges.

A disc drive **100** according to the present invention includes a housing **102** supporting a rotatable recording disc **106**. Spindle motor **108** is supported by the housing to rotate disc **106**. An actuator assembly includes suspension **112** supporting transducing head **110**. An elongated actuator arm supports the suspension within the housing and is movable to position head **110** at a selected radial position adjacent disc **106**. The arm has an aerodynamic cross-section formed by forward edge **502, 702, 902, 1102**, rear edge **504, 704, 904, 1104**, top surface **512, 706, 914, 1106** and bottom surface **514, 708, 916, 1108**. Fluid flow **134** due to rotation of disc **106** engages the forward edge and flows across the width of the arm along the top and bottom surfaces past the rear edge.

It is to be understood that even though numerous characteristics and advantages of various embodiments of the present invention have been set forth in the foregoing description, together with details of the structure and function of various embodiments of the invention, this disclosure is illustrative only, and changes may be made in details, especially in matters of structure and arrangement of parts within the principles of the present invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed. For example, particular elements may vary depending on the particular application for the actuator arm while maintaining substantially the same functionality without departing from the scope and spirit of the present invention. While the actuator arm is shown and described as symmetrical about the respective center planes, it may be desirable to provide non-symmetrical flaps and stabilizers to provide stabilization of the air flow. In addition, although the preferred embodiments described herein are directed to specific configurations of symmetrical actuator arms to minimize vortices, it will be appreciated by those skilled in the art that the teachings of the present invention can be applied to other configurations, such as by combining the forward and rear edges in various combinations, to various combinations of configurations along the length of a given actuator arm, and to various types of disc drives including magnetic disc drives, optical disc drives, single-disc disc drives and multiple-disc disc drives, all without departing from the scope and spirit of the invention.

What is claimed is:

1. A disc drive actuator arm for positioning a head relative to a track on a rotating disc, the actuator arm comprising a body of extended length having:

a top surface substantially continuously curved on one side of a mid-plane, the top surface extending from a forward edge to a rear edge, with the forward and rear edges defining a width of the body and the forward edge being arranged to engage the fluid flow due to rotation of the disc so that fluid flows along the top surface to the rear edge, and

a bottom surface along which fluid flows, the bottom surface being substantially continuously curved on another side of the mid-plane such that the top surface and the bottom surface are substantially symmetrical about the mid-plane, the bottom surface joined to the top surface at the forward and rear edges, wherein the top and bottom surfaces are so arranged in relation to each other that the fluid flow has a first boundary layer along the top surface and a second boundary layer along the bottom surface, the top and bottom surfaces defining an aerodynamic profile across the width of the body so that the boundary layers do not significantly separate along the top and bottom surfaces or at the forward and rear edges and fluid flow is substantially laminar past the arm from the forward edge to the rear edge to prevent vortex shedding from the rear edge and the top and bottom surfaces; and wherein the top surface and the bottom surface each has an elliptical shape in cross-section so that the forward and rear edges are formed at the intersections of the top and bottom surfaces.

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